

FORM PTO-1390 (REV. 5-93)	U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER 2345/159
<b>TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371</b>		U.S. APPLICATION NO. (If known, see 37 CFR 1.5) <b>09/890597</b>
INTERNATIONAL APPLICATION NO. <b>PCT/EP00/00320</b>	INTERNATIONAL FILING DATE <b>17 January 2000 (17.01.00)</b>	PRIORITY DATE CLAIMED: <b>03 February 1999 (03.02.99)</b>
<b>TITLE</b> REDUCTION OF THE DISTORTION OF OPTICAL IMPULSES THROUGH POLARISATION MODE DISPERSION IN OPTICAL TRANSMISSION SYSTEMS		
<b>APPLICANT(S) FOR DO/EO/US</b> DULTZ, Wolfgang; BERESNEV, Leonid; FRINS, Erna; KUEPPERS, Franko; SCHMITZER, Heidrun; VOBIAN, Joachim; and WEIERSHAUSEN, Werner		
Applicant(s) herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information		
<ol style="list-style-type: none"> <li>1. <input checked="" type="checkbox"/> This is a <b>FIRST</b> submission of items concerning a filing under 35 U.S.C. 371.</li> <li>2. <input type="checkbox"/> This is a <b>SECOND</b> or <b>SUBSEQUENT</b> submission of items concerning a filing under 35 U.S.C. 371.</li> <li>3. <input checked="" type="checkbox"/> This is an express request to begin national examination procedures (35 U.S.C. 371(f)) immediately rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).</li> <li>4. <input checked="" type="checkbox"/> A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.</li> <li>5. <input checked="" type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371(c)(2))             <ol style="list-style-type: none"> <li>a. <input type="checkbox"/> is transmitted herewith (required only if not transmitted by the International Bureau).</li> <li>b. <input checked="" type="checkbox"/> has been transmitted by the International Bureau.</li> <li>c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US)</li> </ol> </li> <li>6. <input checked="" type="checkbox"/> A translation of the International Application into English (35 U.S.C. 371(c)(2)).</li> <li>7. <input checked="" type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))             <ol style="list-style-type: none"> <li>a. <input type="checkbox"/> are transmitted herewith (required only if not transmitted by the International Bureau).</li> <li>b. <input type="checkbox"/> have been transmitted by the International Bureau.</li> <li>c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired.</li> <li>d. <input checked="" type="checkbox"/> have not been made and will not be made.</li> </ol> </li> <li>8. <input type="checkbox"/> A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).</li> <li>9. <input checked="" type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). (UNSIGNED)</li> <li>10. <input checked="" type="checkbox"/> A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).</li> </ol>		
<b>Items 11. to 16. below concern other document(s) or information included:</b>		
<ol style="list-style-type: none"> <li>11. <input checked="" type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98.</li> <li>12. <input type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.</li> <li>13. <input checked="" type="checkbox"/> A <b>FIRST</b> preliminary amendment.               <input type="checkbox"/> A <b>SECOND</b> or <b>SUBSEQUENT</b> preliminary amendment.           </li> <li>14. <input checked="" type="checkbox"/> A substitute specification and a marked up version of the substitute specification.</li> <li>15. <input type="checkbox"/> A change of power of attorney and/or address letter.</li> <li>16. <input checked="" type="checkbox"/> Other items or information: International Search Report; International Preliminary Examination Report; and Form PCT/RO/101.</li> </ol>		

Express Mail No.: EL244503832

U.S. APPLICATION NO. if known, see 37 CFR 1.492(e)

09/890597

INTERNATIONAL APPLICATION NO  
PCT/EP00/00320ATTORNEY'S DOCKET NUMBER  
2345/159

17.  The following fees are submitted:

**Basic National Fee (37 CFR 1.492(a)(1)-(5)):**

Search Report has been prepared by the EPO or JPO ..... \$860.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) ..... \$690.00

No international preliminary examination fee paid to USPTO (37 CFR 1.482) but  
international search fee paid to USPTO (37 CFR 1.445(a)(2)) ..... \$710.00Neither international preliminary examination fee (37 CFR 1.482) nor international  
search fee (37 CFR 1.445(a)(2)) paid to USPTO ..... \$1,000.00International preliminary examination fee paid to USPTO (37 CFR 1.482) and all  
claims satisfied provisions of PCT Article 33(2)-(4) ..... \$100.00

CALCULATIONS | PTO USE ONLY

**ENTER APPROPRIATE BASIC FEE AMOUNT =** \$ 860Surcharge of \$130.00 for furnishing the oath or declaration later than  20  30 months  
from the earliest claimed priority date (37 CFR 1.492(e)).

\$

Claims	Number Filed	Number Extra	Rate	
Total Claims	12 - 20 =	0	X \$18.00	\$0
Independent Claims	2 - 3 =	0	X \$80.00	\$0
Multiple dependent claim(s) (if applicable)			+ \$270.00	\$

**TOTAL OF ABOVE CALCULATIONS =** \$860Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must  
also be filed. (Note 37 CFR 1.9, 1.27, 1.28).

\$

**SUBTOTAL =** \$860Processing fee of \$130.00 for furnishing the English translation later the  20  30  
months from the earliest claimed priority date (37 CFR 1.492(f)).

+

**TOTAL NATIONAL FEE =** \$860Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be  
accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property

+

**TOTAL FEES ENCLOSED =** \$860Amount to be  
refunded  
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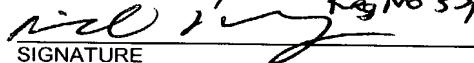
\$

\$

- a.  A check in the amount of \$\_\_\_\_\_ to cover the above fees is enclosed.
- b.  Please charge my Deposit Account No. 11-0600 in the amount of \$860.00 to cover the above fees. A duplicate copy of this  
sheet is enclosed.
- c.  The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to  
Deposit Account No. 11-0600. A duplicate copy of this sheet is enclosed.

**NOTE:** Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or  
(b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:  
Kenyon & Kenyon  
One Broadway  
New York, New York 10004  
Telephone No. (212)425-7200  
Facsimile No. (212)425-5288



SIGNATURE

Richard L. Mayer, Reg. No. 22,490

NAME

8/3/01

DATE

CUSTOMER NO. 26646

09/890597  
JC05 Rec'd PCT/PTO 03 AUG 2005

2345/159

EXPRESS MAIL CERTIFICATE

"EXPRESS MAIL" MAILING LABEL NUMBER EL244503832

DATE OF DEPOSIT 8/3/01

TYPE OF DOCUMENT Nat'l Phase App. of Dultz et al.  
"Reduction of the Distortion of Optical Impulses..."

SERIAL NO. To be Assigned FILING DATE Herewith

I HEREBY CERTIFY THAT THIS PAPER OR FEE IS BEING DEPOSITED WITH THE UNITED STATES POSTAL SERVICE "EXPRESS MAIL POST OFFICE TO ADDRESSEE" SERVICE UNDER 37 CFR 1.10 ON THE DATE INDICATED ABOVE, BY BEING HANDED TO A POSTAL CLERK OR BY BEING PLACED IN THE EXPRESS MAIL BOX BEFORE THE POSTED DATE OF THE LAST PICK UP, AND IS ADDRESSED TO THE ASSISTANT COMMISSIONER FOR PATENTS, WASHINGTON, D.C. 20231.

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(PRINTED NAME OF PERSON MAILING PAPER OR FEE)

  
(SIGNATURE OF PERSON MAILING PAPER OR FEE)

10 Rec'd 83 RUE 2001

[2345/159]

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

Applicant(s) : Wolfgang DULTZ et al.  
Serial No. : To Be Assigned  
Filed : Herewith  
For : REDUCTION OF THE DISTORTION OF OPTICAL  
IMPULSES THROUGH POLARISATION MODE  
DISPERSION IN OPTICAL TRANSMISSION SYSTEMS  
Art Unit : To Be Assigned  
Examiner : To Be Assigned

Assistant Commissioner  
for Patents  
Washington, D.C. 20231

**PRELIMINARY AMENDMENT AND**  
**37 C.F.R. § 1.125 SUBSTITUTE SPECIFICATION STATEMENT**

SIR:

Please amend without prejudice the above-identified application before examination, as set forth below.

**IN THE TITLE:**

Please replace the title with the following:

--REDUCING THE DISTORTION OF OPTICAL PULSES CAUSED BY POLARIZATION MODE DISPERSION IN OPTICAL COMMUNICATION SYSTEMS--.

**IN THE SPECIFICATION AND ABSTRACT:**

In accordance with 37 C.F.R. § 1.121(b)(3), a Substitute Specification (including the Abstract, but without claims) accompanies this response. It is respectfully requested that the Substitute Specification (including Abstract) be entered to replace the Specification of record.

EL244503832

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The Substitute Specification reflects the text of Revised Pages 1, 2, 2a, 2b, 16, 17, and 18, associated with the International Preliminary Examination Report.

**IN THE CLAIMS:**

Without prejudice, please cancel original claims 1 to 12 in the original application and please cancel substitute claims 1 to 12 from the Revised Pages, and please add new claims 13 to 24 as follows:

13. (New) A method for reducing distortion of an optical pulse contained in a communication-transmitting luminous flux in an optical communication system caused by polarization mode dispersion, comprising:

driving a polarization-controlling device to adjust a polarization of the optical pulse so that a transmission quality of the optical communication system is maximized, wherein the driving of the polarization-controlling device functions in response to the transmission quality detected; and

using a small, coupled-out portion of the communication-transmitting luminous flux to determine the transmission quality of the optical communication system.

14. (New) The method of claim 13, further comprising:

resetting the polarization of the optical pulse in predefined time intervals for optimizing communication.

15. (New) The method of claim 13, wherein the polarization of the optical pulse is controlled at an input end of the optical communication system.

16. (New) The method of claim 13, further comprising:

altering the polarization of the optical pulse at an output end of the optical communication system using the polarization-controlling device,

wherein the optical pulse propagates through an analyzer following the optical communication system.

17. (New) An optical communication system having reducible distortion of an optical pulse propagating through the optical communication system and contained in a communication-transmitting luminous flux, comprising:

an optical transmission medium for transmitting the optical pulse;

a determining device to determine a transmission quality of the optical communication system, the determining device having an output;

a polarization-controlling device;

a regulating device having an input;

a beam splitter for coupling out and supplying a small portion of the communication-transmitting luminous flux to the determining device;

wherein a signal from the output of the determining device is applied to the input of the regulating device, and

wherein the regulating device is configured to drive the polarization-controlling device for changing a polarization of the optical pulse so that the transmission quality is optimized.

18. (New) The optical communication system of claim 17, wherein the polarization-controlling device is disposed at the input of the optical transmission medium.

19. (New) The optical communication system of claim 17, further comprising:

an analyzer, the analyzer being disposed in a propagation direction of a light, downstream from the polarization-controlling device; and

wherein the polarization-controlling device is disposed at the output of the optical transmission medium.

20. (New) The optical communication system of claim 17, wherein the polarization-controlling device includes a first  $\lambda/4$  delay element, a  $\lambda/2$  delay element and a second  $\lambda/4$  delay element, the first  $\lambda/4$ ,  $\lambda/2$  and second  $\lambda/4$  delay elements being disposed in series as  $\lambda/4-\lambda/2-\lambda/4$  and being adjustable.

21. (New) The optical communication system of claim 19, wherein the analyzer is a linear analyzer, and the polarization-controlling device includes at least an adjustable  $\lambda/4$  delay element and an adjustable  $\lambda/2$  delay element.

22. (New) The optical communication system of claim 21, wherein at least one delay element includes a liquid crystal element.

23. (New) The optical communication system of claim 21, wherein at least one delay element includes an electro-optical crystal.

24. (New) The optical communication system of claim 21, wherein at least one delay element includes at least one of a mechanically adjustable element, an electromotively adjustable element and a piezoelectrically adjustable element of three fiber loops.

#### REMARKS

This Preliminary Amendment cancels without prejudice original claims 1 to 12 and substitute claims 1 to 12 in the underlying PCT Application No. PCT/EP00/00320, and adds without prejudice new claims 13 to 24. The new claims conform the claims to U.S. Patent and Trademark Office rules and do not add new matter to the application.

In accordance with 37 C.F.R. § 1.121(b)(3), the Substitute Specification (including the Abstract, but without the claims) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to U.S. Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. § 1.121(b)(3)(iii) and § 1.125(b)(2), a Marked Up Version Of The Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. In the Marked Up Version, shading indicates added text and bracketing indicates deleted text. Approval and entry of the Substitute Specification (including Abstract) is respectfully requested. The Substitute Specification reflects the text of Revised Pages 1, 2, 2a, 2b, 16, 17, and 18, associated with the International Preliminary Examination Report.

The underlying PCT Application No. PCT/EP00/00320 includes an International Search Report, dated May 10, 2000. The Search Report includes a list of documents that were uncovered in the underlying PCT Application. A copy of the Search Report accompanies this Preliminary Amendment.

The underlying PCT Application No. PCT/EP00/00320 also includes an International Preliminary Examination Report, dated April 6, 2001, and an annex (including substitute claims 1 to 12 and the specification text of Revised Pages 1, 2, 2a, 2b, 16, 17, and

18, associated with the International Preliminary Examination Report). An English translation of the International Preliminary Examination Report and of the annex accompanies this Preliminary Amendment.

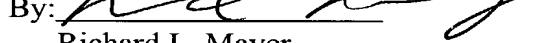
Applicants assert that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully Submitted,

KENYON & KENYON

By:   
B No 35,952

Dated: 8/3/01

By: 

Richard L. Mayer  
(Reg. No. 22,490)  
One Broadway  
New York, NY 10004  
(212) 425-7200 (telephone)  
(212) 425-5288 (facsimile)

**CUSTOMER NO. 26646**

REDUCING THE DISTORTION OF OPTICAL PULSES  
CAUSED BY POLARIZATION MODE DISPERSION IN OPTICAL  
COMMUNICATION SYSTEMS

FIELD OF THE INVENTION

The present invention relates to a method for reducing the distortion of optical pulses in optical communication systems, and to an optical communication system having reduced spreading of the optical pulses propagating through the system.

BACKGROUND INFORMATION

In optical communications, optical components, such as optical elements and glass fibers, which are only isotropic in the first approximation or which are innately anisotropic are believed to be used. For example, the glass fibers employed in photonic networks may exhibit optical anisotropies due to the manufacturing process and design or due to other circumstances, such as temperature and pressure fluctuations, as well as because of the bending of the fiber itself. These, in part, location-dependent anisotropies may also produce an optical birefringence (or double refraction), which can also vary from location to location in the fiber. The birefringence (or double refraction) may result in two orthogonally polarized natural waves of the light propagating at a different phase velocity in one fiber section under consideration. When an optical signal, e.g., an optical pulse having any polarization, is transmitted through the fiber, the optical pulse is believed to become distorted, i.e., spreads during the course of propagation, due to the difference in the velocity of the various polarization components. This spreading of the optical pulses may limit the transmission rate in the communication system.

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The reference of "Optical Equalization of Polarization

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Dispersion", J.H. Winters et al., Proceedings of the STIE, January 1, 1992, discusses an optical equalizing system, which can be used to reduce the influences of polarization mode dispersion. It is believed that to generate the control signals for the polarization-controlling elements, the optical received signal is received in its entirety in one or a plurality of receivers and is analyzed accordingly. A further transmission of the optical signal is believed to be no longer possible.

The U.S. Patent No. 5,793,511 discusses an optical receiver having an equalizing circuit which is able to equalize an optical signal distorted by polarization mode dispersion. For this, the received optical signal is converted into two electrical components, of these, the equalizing circuit generating a quality signal for driving a polarization control element implemented in the receiver.

The European Patent Publication No. 0 716 516 discusses a polarization-diversity detection technique for optical signals transmitted over a single-mode fiber. To compensate for distortions caused by polarization mode dispersions in the fiber, a polarization-diversity detection is carried out. For this, it is believed that the optical received signal is initially separated by a polarization beam splitter into a first and second polarization component. A control signal is believed to be subsequently generated to control a polarization-control element as a function of the phase difference between the two polarization components.

SUMMARY OF THE INVENTION  
An exemplary embodiment of the present invention is directed to providing a method for reducing the distortion of optical pulses in optical communication systems caused by polarization mode dispersion, which can be implemented cost-effectively, flexibly adapted to the particular optical communication

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system, and which also allows for dynamic fluctuations with respect to the birefringence. Exemplary embodiments of the present invention are further directed to providing a suitable optical communication system in part which may effect the 5 method for reducing the distortion of optical pulses in optical communication systems caused by polarization mode dispersion.

To keep the transmission quality in the optical communication 10 system at an optimal value, the transmission quality is measured, and a signal indicative thereof is applied to a regulating device, which drives a polarization-controlling device to alter the polarization state of the communication-transmitting optical pulses. The regulating device controls 15 the polarization of the optical pulses in such a way that the transmission quality is optimized. A small coupled-out portion of the communication-transmitting luminous flux may be used to determine the transmission quality.

20 Any transmission device at all, for example, an optical fiber or other optical component, can be composed with respect to its birefringence properties, of a number of double-refracting plates, each of which has a different, statistically varying birefringence, delay and orientation. A double-refracting 25 plate assembly of this kind is characteristic for a specific wavelength and is, therefore, dependent upon the frequency of the incident light.

An actual glass fiber may be constituted of a plate assembly, 30 which is not characterized by a stochastic system (or arrangement) of double-refracting plates, but rather that there is at least one preferred, i.e., substantially constant, birefringence in specific sections of the fiber. This means that the optical properties in the mentioned fiber sections 35 can be specified by a single, thick and/or heavily double-refracting plate. An information signal, which

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propagates within such a section in the sense of an optical pulse and which couples to the same extent into both (intrinsic) polarization states of the substantially constant birefringent fiber member, is split into two pulses of the 5 same intensity, but of orthogonal polarization. Both pulse components exhibit a different group velocity in the medium, so that an especially high distortion, i.e., spreading of the originally injected signal pulse, occurs due to the polarization mode dispersion, which limits the communication 10 transmission rate, in particular.

An exemplary embodiment of the present invention is directed to assuring that the optical pulse propagates within the optical communication system having at least one section with preferred or substantially constant birefringence, in such a way that, in the at least one section, the signal exhibits a polarization which corresponds to one of the two main polarization states of the section, e.g., a fiber member. As a 15 result, the pulse shape may not be broadened during transmission by the section having preferred or substantially 20 constant birefringence. Within the section having preferred birefringence, the optical pulses propagate only in one of the two possible channels, i.e., either in the channel having a high rate of propagation or in the channel having the slow 25 rate of propagation, so that the optical pulses are not thereby split or widened, but only accelerated or delayed. This may have no adverse effect on the transmission rate, since the entire pulse sequence experiences an acceleration or delay. It is, thus, assured that the section of the optical 30 transmission medium which exhibits a preferred or substantially constant birefringence and, therefore, may substantially contribute to the widening of the optical pulses, is "eliminated" with respect to the polarization mode dispersion within the entire communication system. The 35 remaining broadening of the optical pulse may only still be caused by the remaining sections of the communication system,

which can be described, for example, as a stochastic system or arrangement of thin, double-refracting plates. However, the extent to which these other sections of the communication system cause the optical pulse to widen is much less than the  
5 possible distortion of the pulse within the section having preferred or substantially constant birefringence, for the case that the light does not traverse the last-mentioned section in only one of the main polarization states.

10 The exemplary embodiments of the present invention are directed to providing that when the optical pulses are modified by the polarization-controlling device before entering into the optical communication system, such that the section having preferred or substantially constant  
15 birefringence is traversed in one of the main polarization states of the section and when only that portion of the optical information signal which is transmitted in one of the main polarization states of the section having preferred or substantially constant birefringence, through this section, is  
20 considered for the data transmission. Both cases are based on the elucidated principle of the present invention and, accordingly, are equivalent.

25 To alter the polarization of the information signal in accordance with the present invention, the polarization-controlling device is driven by the regulating device in such a way that the transmission quality is maximized. This regulated, maximal transmission quality corresponds accordingly, for example, to the case when the  
30 optical information signal propagates within the section having preferred or substantially constant birefringence in one of the two main polarization states, or when only that portion of the optical information signal, which this applies to, is considered.

35 Another exemplary embodiment of the present invention is

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directed to providing for repeatedly maximizing the transmission quality at spaced apart time intervals. The time-related fluctuations in the magnitude and orientation of the birefringence, which can have a negative effect on the distortion of the optical pulses can be diminished. These fluctuations, induced, for example, by temperature fluctuations in an optical fiber, may have the effect that the optical pulses no longer traverse the section having preferred or substantially constant birefringence in one of its main polarization states. By maximizing the transmission quality in repeated, spaced-apart time intervals, one cancels (or reverses) the spreading of the optical pulse caused by the fluctuations.

To allow for the variation over time in the polarization state at the input of the optical communication system, the polarization-controlling device can be connected upstream from the communication system. By regulating the polarization-controlling device, one assures that the section having preferred or substantially constant birefringence is traversed by the optical pulses in one of the two main polarization states of the section, in spite of the birefringence fluctuating over time in magnitude and orientation within the communication system.

To losslessly convert the light into the required polarization state, the polarization-controlling device can include a  $\lambda/4$ -, a  $\lambda/2$ - and a further  $\lambda/4$  delay element, the delay elements being disposed one behind the other and each being adjustable. Using such a polarization-controlling device, light, for example light pulses having any polarization state at all, can be changed into light having a different, desired polarization state.

The polarization-controlling device can also be placed at the output of the communication system, however. This may simplify

the control, since the determination of transmission quality, the control, and the polarization-controlling device are implemented at the same location. To consider only that component of the light which has propagated in the section having preferred or substantially constant birefringence in one of the main polarization states, an analyzer may be additionally configured downstream from the polarization-controlling elements.

If the analyzer is a linear analyzer, then the polarization-controlling device may be simplified to include only a  $\lambda/4$ - and a  $\lambda/2$ -delay element, each being adjustable, i.e., rotatable. Using a polarization-controlling device of this kind, light having any polarization at all - in this case light transmitted in one of its main polarization states through the portion having preferred birefringence - can be changed into light having a linear polarization - in this case light which is polarized in the transmit direction toward the analyzer.

The delay elements used can include a liquid crystal element or an electro-optic crystal, depending on the special application involved, for example, depending on the wavelength employed. In embodiments of the present invention, the adjusting elements may be readjusted without a driving mechanism, i.e., electrically. If the control takes place at frequencies which are not too high, simple, mechanically movable controlling elements may also be used.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows an exemplary embodiment of the present invention where the polarization-controlling element is positioned upstream from the optical communication system.

Figure 2 shows an exemplary embodiment of the present invention where the polarization-controlling element is placed

at the output end of the communication system.

DETAILED DESCRIPTION

The optical communication system having reduced distortion of  
5 the optical pulses passing through the system may include an  
optical transmission medium that is composed of various  
sections. These may include optical components, such as fiber  
couplers, switches, amplifiers, and other components, optical  
lines or fibers. At least one section of the communication  
10 system may exhibit a preferred or substantially constant  
birefringence. The optical communication system in accordance  
with the present invention may include a device for  
determining the transmission quality at the end of the  
communication system. This device may generate an output  
15 signal which is dependent upon the transmission quality and  
which is applied to the input of a regulating device. This  
regulating device drives a polarization-controlling device,  
through which the optical pulses are transmitted and which is,  
therefore, set up, or designed, for altering the polarization  
20 of the optical pulses. Functioning in response to the detected  
transmission quality of the communication system, the  
polarization-controlling device is driven to maximize the  
transmission quality; i.e., the various parameters for setting  
the controlling elements of the polarization-controlling  
25 device continue to be modified until the transmission quality  
is optimal and can no longer be improved. The  
polarization-controlling element may be regulated so that the  
transmission quality is measured; the controlling element is  
subsequently slightly reset (or readjusted) in any direction  
30 within a parameter space.

The transmission quality may subsequently be measured again.  
If the transmission quality has become greater, the regulating  
device resets the controlling element further in this  
35 direction; otherwise it does so in the opposite direction. If  
the transmission quality changes slightly or not at all, then

the regulating device resets the polarization-controlling element in a direction that is orthogonal to the first direction in the parameter space. This method may lead to a local maximum of the transmission quality in the parameter space of the polarization-controlling element. The method may be repeated in specific intervals, which keeps the transmission quality of the communication system at a high level.

To ascertain the transmission quality, one can use the bit error rate, for example. It may be determined using special measuring instruments and indicates, as a ratio, how many read errors occur in a known sequence of transmitted pulses. Another exemplary embodiment of the present invention is directed to providing for the so-called eye pattern to be used as a measure of the transmission quality of the communication system. In addition, the polarization mode dispersion itself can also be used as a measure of the transmission quality. This may only be determined with relatively substantial outlay, as is the case for the bit error rate and the eye diagram. The exemplary embodiment of the present invention may be directed to using the redundancy monitoring employed in many digital transmission methods to obtain a measure of the transmission error and, thus, of the transmission quality in the communication system.

In the case of the redundancy monitoring, the so-called parity information (parity bytes) may be calculated from the payload to be transmitted, and added to the payload. The parity information may be obtained by performing a simple calculation. It is presently defined for optical communication systems having a synchronous digital hierarchy as the remainder from a quotient formed from the payload code and a preset key code. The parity information may be extracted and any data blocks having faulty information at all points on the optical transmission link where digital analysis of the

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signals is possible may be immediately recognized. In contrast to the bit error rate, the described redundancy monitoring may only permit one data block error rate to be determined, since each parity byte has assigned to it one complete data record  
5 which, accordingly, may only be checked as a whole. Since typically, however, in the case of signal distortion, such as in the case of optical pulse spreading due to polarization mode dispersion, no so-called burst errors occur, i.e., the errors are distributed more or less equally over time, the  
10 redundancy monitoring and a signal Q derived therefrom as an input signal may be suited for the regulating device.

Figure 1 depicts an exemplary embodiment of an optical communication system 1 in accordance with the present invention having reduced distortion of the information signal propagating through the system. The optical information signal may be transmitted in the form of optical pulses through a polarization-controlling element 3, before entering into the optical transmission medium 5. This optical transmission  
15 medium 5 may include various sections 5', 5'', 5''', in the present example, section 5'' being a section in which a preferred birefringence occurs. The optical transmission medium may be constituted of an optical fiber line. The other sections 5', 5''' exhibit a stochastic distribution with respect to the birefringence. Accordingly, these regions are  
20 able to be characterized by a random arrangement of double-refracting plates. Behind (or downstream from) the transmission medium, the optical information signal, for example an optical pulse, may be incident to a beam splitter  
25 7, which couples out a small portion of the communication-transmitting luminous flux. A detector 8 may convert the coupled-out portion of the information signal into an electric signal, which may be applied to a device 2 for determining the transmission quality of communication system  
30 1. By the redundancy monitoring, a signal Q, which is a measure of the transmission quality, may be generated in  
35

device 2. This signal may be conducted via a data line 9, which essentially runs in parallel to optical transmission medium 5, as an input signal to regulating device 4. In an embodiment of the present invention, data line 9 may be a spectral channel of optical fiber 5. The regulating device may drive polarization-controlling device 3 to change the polarization of information signal I.

To reduce the distortion, for example, the spreading of information signals, such as of the optical pulses, in response to the detected transmission quality of communication system 1, polarization-controlling device 3 is driven by regulating device 2 to maximize the transmission quality. As a consequence of the above described control, the light in section 5'' exhibiting the preferred or substantially constant birefringence has a polarization that corresponds to one of the main polarization states of the section, so that, within this region, no distortion occurs, i.e., the signal does not spread. Thus, with respect to the polarization mode dispersion, that region is "eliminated", which otherwise would substantially contribute to the distortion of the signal.

To compensate for time-related fluctuations of the birefringence and consequences resulting therefrom, provision may be made for the transmission quality to be repeatedly maximized at spaced apart time intervals. In this manner, at any particular point in time, the light within section 5'' having the preferred or substantially constant birefringence may be always polarized in parallel to one of the main polarization states of the transmission medium section.

Referring Figure 1, the polarization-controlling device 3 includes a  $\lambda/4$ -, a  $\lambda/2$ - and a further  $\lambda/4$  delay element, these delay elements being disposed one behind the other and each being adjustable, i.e., rotatable. The three degrees of freedom of the polarization-controlling device are regulated

by regulating device 4 in accordance with the method of the present invention. Using the entire polarization-controlling device 3, each desired polarization is able to be converted into another desired polarization. Delay elements can include 5 liquid crystal elements, electro-optic crystals, or mechanically, electromotively or piezoelectrically adjustable delay elements, such as fiber loops.

Figure 2 depicts an embodiment of the present invention, where 10 polarization-controlling device 3 is configured downstream from the communication system which includes transmission medium 5 having at least one section 5'' exhibiting a preferred birefringence. Situated in this specific embodiment downstream from the polarization-controlling device, is an 15 analyzer 6, which may absorb or deflect the signal-spreading or signal-distorting polarization components of the optical information flow, depending on the specific embodiment of the analyzer. A small portion of the information flow is split (or separated) off by beam splitter 7 and supplied to detector 8. 20 Its output signal is fed to a regulating device 2, which generates a signal Q that is a measure indicative of the transmission quality. This signal, in turn, is the input quantity for regulating device 4, which drives polarization-controlling device 3. The analyzer 6 may include 25 a linear polarizer, so that the polarization-controlling element merely needs to still transform any particular polarization state into a fixed, linear polarization state. This may be done using a  $\lambda/4$ - and a  $\lambda/2$ -delay element, which are disposed in series (or one behind the other) and are each 30 adjustable, i.e., rotatable.

The polarization-controlling device may be adjusted when the light which, in the fiber member having preferred or substantially constant birefringence, assumed the one main 35 polarization state, may be imaged onto the light having the transmit polarization of the analyzer, whereas the light,

## SUBSTITUTE SPECIFICATION

which assumed the other polarization state, is imaged onto the light having the blocking polarization state of the linear polarizer. The light which is imaged onto the transmit polarization of the analyzer may exhibit the higher intensity portion of the entire signal intensity. Thus, the control unit may be set up such that, in response to too low optical intensity of the information flow downstream from the analyzer, the control unit may switch over to the other main polarization direction of the section of the communication system, such as fiber member 5", having the preferred or substantially constant birefringence.

A further exemplary embodiment of the present inventions, in place of beam splitter 7 and detector 8 in Figures 1 and 2, is directed to providing that the transmission quality be measured at the same time that the information itself is detected, directly by the main detector at the output of the transmission link.

ABSTRACT OF THE DISCLOSURE

A method and device for reducing the distortion of optical  
5 pulses caused by the polarization mode dispersion in optical  
communication systems is provided. When an optical pulse  
having any polarization is transmitted through an optical  
communication system, which is optically anisotropic, at least  
in sections, the optical pulse may become distorted due to the  
10 different velocities of the various polarization components.  
This distortion of the optical pulses may reduce the maximum  
transmission rate of the system. A method is provided for  
functioning in response to the detected transmission quality  
of the communication system where a polarization-controlling  
15 device for setting the polarization of the optical pulse is  
driven in such a way that the transmission quality is  
maximized. An optical communication system, including an  
optical transmission medium, involves a device for determining  
the transmission quality of the communication system, a  
20 regulating device, and a polarization-controlling device. The  
output signal from the device for determining the transmission  
quality of the communication system may be applied to the  
regulating device, which drives the polarization-controlling  
device to change the polarization of the optical pulses in  
25 such a way that the transmission quality is optimized.

2/PARTS

[2345/159]

REDUCING THE DISTORTION OF OPTICAL PULSES  
CAUSED BY POLARIZATION MODE DISPERSION IN OPTICAL  
COMMUNICATION SYSTEMS

The present invention relates to a method for reducing the distortion of optical pulses in optical communication systems, as recited in Claim 1, and to an optical communication system having reduced spreading of the optical pulses propagating through the system, as recited in Claim 5.

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In optical communications, optical components, such as optical elements and glass fibers are often used, which are only isotropic in the first approximation, or which are innately anisotropic. For example, the glass fibers employed in photonic networks generally exhibit optical anisotropies due to the manufacturing process and design or due to other circumstances, such as temperature and pressure fluctuations, as well as because of the bending of the fiber itself. These, in part, location-dependent anisotropies also produce an optical birefringence, which can also vary from location to location in the fiber. The birefringence causes two orthogonally polarized natural waves of the light to propagate at different phase velocities in one fiber section under consideration. This means that, in the general case when an optical signal, in particular an optical pulse having any polarization at all, is transmitted through the fiber, the optical pulse becomes distorted, i.e., spreads during the course of propagation, due to the difference in the velocity of the various polarization components. This spreading of the optical pulses limits, in particular, the transmission rate in the communication system.

The object of the present invention is to provide a method for reducing the distortion of optical pulses in optical communication systems caused by polarization mode dispersion, which can be implemented cost-effectively, flexibly adapted to

the particular optical communication system, and, in particular, which also allows for dynamic fluctuations with respect to the birefringence. A further aim is to provide a suitable optical communication system, which will not have the mentioned disadvantages of the related art systems.

5 This technical objective is achieved by the present invention, on the one hand, by the method steps which include the features of Claim 1 and, on the other hand, by the features of  
10 Claim 5.

To keep the transmission quality in the optical communication system at an optimal value, the transmission quality is measured, and a signal indicative thereof is applied to a  
15 regulating device, which drives a polarization-controlling device to alter the polarization state of the optical pulses. The regulating device controls the polarization of the optical pulses in such a way that the transmission quality is optimized.

20 Generally, any transmission device at all, for example an optical fiber or other optical component, can be produced with respect to its birefringence properties, from a number of double-refracting plates, each of which has a different,  
25 statistically varying birefringence, delay and orientation. A double-refracting plate assembly of this kind is characteristic for a specific wavelength and is, therefore, dependent upon the frequency of the incident light.

30 The present invention is based on the realization that, for example, an actual glass fiber is generally constituted of a plate assembly, which is not characterized by a stochastic system of double-refracting plates, but rather that there is at least one preferred, i.e., substantially constant  
35 birefringence in specific sections of the fiber. This means that the optical properties in the mentioned fiber sections can be specified by a single, thick and/or heavily

double-refracting plate. An information signal, which propagates within such a section in the sense of an optical pulse and which couples to the same extent into both (intrinsic) polarization states of the preferably birefringent 5 fiber member, is split into two pulses of the same intensity, but of orthogonal polarization. Both pulse components exhibit a different group velocity in the medium, so that an especially high distortion, i.e., spreading of the originally injected signal pulse, occurs due to the polarization mode 10 dispersion, which limits the communication transmission rate, in particular.

The underlying principle of the present invention is to assure 15 that the optical pulse propagates within the optical communication system having at least one section with preferred birefringence, in such a way that, in the mentioned section, the signal exhibits a polarization which corresponds to one of the two main polarization states of the section, for example of a fiber member. As a result, the pulse shape is not 20 broadened during transmission by the section having preferred birefringence. Within the section having preferred birefringence, the optical pulses propagate only in one of the two possible channels, i.e., either in the one having a high rate of propagation or in the one having the slow rate of 25 propagation, so that the optical pulses are not thereby split or widened, but only accelerated or delayed. However, this has no adverse effect on the transmission rate, since the entire pulse sequence experiences an acceleration or delay. It is, thus, assured that the section of the optical transmission 30 medium which exhibits a preferred birefringence and, therefore, can substantially contribute to the widening of the optical pulses, is "eliminated" with respect to the polarization mode dispersion within the entire communication system. Thus, the remaining broadening of the optical pulse is 35 only still caused by the remaining sections of the communication system, which can be described, for example, as a stochastic system of thin, double-refracting plates.

However, the extent to which these other sections of the communication system cause the optical pulse to widen is much less than the possible distortion of the pulse within the section having preferred birefringence, for the case that the 5 light does not traverse the last-mentioned section in only one of the main polarization states.

The above explanations apply, on the one hand, for the case when the optical pulses are modified by the 10 polarization-controlling device before entering into the optical communication system, such that the section having preferred birefringence is traversed in one of the main polarization states of the section and, on the other hand, also applies to the case when only that portion of the optical 15 information signal which is transmitted in one of the main polarization states of the section having preferred birefringence, through this section, is considered for the data transmission. Both cases are based on the elucidated principle of the present invention and, accordingly, are 20 equivalent.

To alter the polarization of the information signal in accordance with the present invention, the polarization-controlling device is driven by the regulating 25 device in such a way that the transmission quality is maximized. This regulated, maximal transmission quality corresponds accordingly, for example, to the case when the optical information signal propagates within the section having preferred birefringence in one of the two main polarization states, or when only that portion of the optical 30 information signal, which this applies to, is considered. One advantageous specific embodiment of the present invention provides for repeatedly maximizing the transmission quality at spaced apart time intervals. This makes it possible to 35 diminish the time-related fluctuations in the magnitude and orientation of the birefringence, which can have a negative effect on the distortion of the optical pulses. These

fluctuations, mentioned already above, induced, for example, by temperature fluctuations in an optical fiber, can have the effect that the optical pulses no longer traverse the section having preferred birefringence in one of its main polarization states. By maximizing the transmission quality in repeated, spaced-apart time intervals, one cancels the spreading of the optical pulse caused by the fluctuations.

To allow for the variation over time in the polarization state at the input of the optical communication system, the polarization-controlling device can be connected upstream from the communication system. By regulating the polarization-controlling device, one assures that the section having preferred birefringence is traversed by the optical pulses in one of the two main polarization states of the section, in spite of the birefringence fluctuating over time in magnitude and orientation within the communication system.

To losslessly convert the light into the required polarization state, the polarization-controlling device can include a  $\lambda/4$ -, a  $\lambda/2$ - and a further  $\lambda/4$  delay element, the delay elements being disposed one behind the other and each being adjustable. Using such a polarization-controlling device, light, for example light pulses having any polarization state at all, can be changed into light having a different, desired polarization state.

The polarization-controlling device can also be placed at the output of the communication system, however. This simplifies the control, since the determination of transmission quality, the control, and the polarization-controlling device are implemented at the same location. To consider only that component of the light which has propagated in the section having preferred birefringence in one of the main polarization states, an analyzer is additionally configured downstream from the polarization-controlling elements.

If this analyzer is a linear analyzer, then the polarization-controlling device is simplified to the effect that it includes only a  $\lambda/4$ - and a  $\lambda/2$ -delay element, which are each adjustable, i.e., rotatable. Using a polarization-controlling device of this kind, light having any polarization at all - in this case light transmitted in one of its main polarization states through the portion having preferred birefringence - can be changed into light having a linear polarization - in this case light which is polarized in the transmit direction toward the analyzer.

In both the arrangements that make use of the principle of the present invention, as well as in the method, the delay elements used can include a liquid crystal element or an electrooptic crystal, depending on the special application involved, for example depending on the wavelength employed. The advantage of these adjusting elements is that they can be readjusted without a driving mechanism, i.e., electrically. If the control takes place at frequencies which are not too high, simple, mechanically movable controlling elements can also be used.

The present invention is described in the following on the basis of a few exemplary embodiments, reference being made to the drawing, whose figures show:

Figure 1 one specific embodiment of the present invention, where the polarization-controlling element is positioned upstream from the optical communication system; and

Figure 2 one specific embodiment of the present invention, where the polarization-controlling element is placed at the output end of the communication system.

In accordance with the present invention, the optical communication system having reduced distortion of the optical pulses passing through the system includes an optical transmission medium that is composed of various sections. These can include optical components, such as fiber couplers,

switches, amplifiers, and other components, but also optical lines (fibers). At least one section of the communication system exhibits a preferred birefringence. In addition, the optical communication system in accordance with the present invention includes a device for determining the transmission quality at the end of the communication system. This device generates an output signal which is dependent upon the transmission quality and which is applied to the input of a regulating device. This regulating device drives a polarization-controlling device, through which the optical pulses are transmitted and which is, therefore, set up for altering the polarization of the optical pulses. Functioning in response to the detected transmission quality of the communication system, the polarization-controlling device is driven to maximize the transmission quality; i.e., the various parameters for setting the controlling elements of the polarization-controlling device continue to be modified until the transmission quality is optimal and can no longer be improved. In particular, the polarization-controlling element is regulated to the effect that the transmission quality is measured; the controlling element is subsequently slightly reset in any direction within a parameter space.

The transmission quality is subsequently measured once again. If the transmission quality has become greater, the regulating device resets the controlling element further in this direction; otherwise in the opposite direction. If the transmission quality changes slightly or not at all, then the regulating device resets the polarization-controlling element in a direction that is orthogonal to the first in the parameter space. This method leads to a local maximum of the transmission quality in the parameter space of the polarization-controlling element. The method is repeated in specific intervals, which keeps the transmission quality of the communication system at a high level.

To ascertain the transmission quality, one can use the bit

error rate, for example. It is determined using special measuring instruments and indicates, as a ratio, how many read errors occur in a known sequence of transmitted pulses.

Another specific embodiment of the present invention provides for the so-called eye pattern to be used as a measure of the transmission quality of the communication system. In addition, the polarization mode dispersion itself can also be used as a measure of the transmission quality. However, this can only be determined with relatively substantial outlay, as is the case for the bit error rate and the eye diagram. For that reason, most specific embodiments of the present invention make use of the redundancy monitoring employed in many digital transmission methods to obtain a measure of the transmission error and, thus, of the transmission quality in the communication system.

In the case of the redundancy monitoring, the so-called parity information (parity bytes) are calculated from the payload to be transmitted, and added to the payload. The parity information is obtained by performing a simple calculation. It is presently defined for optical communication systems having a synchronous digital hierarchy as the remainder from a quotient formed from the payload code and a preset key code. One can extract the parity information and immediately recognize data blocks having faulty information at all points on the optical transmission link where digital analysis of the signals is possible. In contrast to the bit error rate, the described redundancy monitoring only permits one data block error rate to be determined, since each parity byte has assigned to it one complete data record which, accordingly, can only be checked as a whole. Since typically, however, in the case of signal distortion, i.e., in the case of optical pulse spreading due to polarization mode dispersion, no so-called burst errors occur, i.e., the errors are distributed more or less equally over time, the redundancy monitoring and a signal Q derived therefrom as an input signal are suited for the regulating device.

Figure 1 depicts an exemplary specific embodiment of an optical communication system 1 in accordance with the present invention having reduced distortion of the information signal propagating through the system. The optical information signal 5 is transmitted in the form of optical pulses through a polarization-controlling element 3, before entering into the optical transmission medium 5. This optical transmission medium 5 includes various sections 5', 5'', 5''', in the present example, section 5'' being a section in which a preferred birefringence occurs. In the present instance, the 10 optical transmission medium is constituted of an optical fiber line. The other sections 5', 5''' exhibit a stochastic distribution with respect to the birefringence. Accordingly, these regions are able to be characterized by a random 15 arrangement of double-refracting plates. Behind the transmission medium, the optical information signal, for example an optical pulse, is incident to a beam splitter 7, which couples out a small portion of the communication-transmitting luminous flux. A detector 8 converts the coupled-out portion of the information signal 20 into an electric signal, which is applied to a device 2 for determining the transmission quality of communication system 1. By way of the above described redundancy monitoring, a signal Q, which is a measure of the transmission quality, is 25 generated in device 2. This signal is conducted via a data line 9, which essentially runs in parallel to optical transmission medium 5, as an input signal to regulating device 4. In one specific embodiment of the present invention, data line 9 is a spectral channel of optical fiber 5. The 30 regulating device drives polarization-controlling device 3 to change the polarization of information signal I.

To reduce the distortion, for example the spreading of 35 information signals, i.e., of the optical pulses, in response to the detected transmission quality of communication system 1, polarization-controlling device 3 is driven by regulating device 2 to maximize the transmission quality. As a

consequence of the above described control, the light in section 5'' exhibiting the preferred birefringence has a polarization that corresponds to one of the main polarization states of the section, so that, within this region, no  
5 distortion occurs, i.e., the signal does not spread. Thus, with respect to the polarization mode dispersion, that region is "eliminated", which otherwise would substantially contribute to the distortion of the signal.

10 To compensate for time-related fluctuations of the birefringence and consequences resulting therefrom, provision is made for the transmission quality to be repeatedly maximized at spaced apart time intervals. In this manner, at any particular point in time, the light within section 5''  
15 having the preferred birefringence is always polarized in parallel to one of the main polarization states of the transmission medium section.

The polarization-controlling device 3 in Figure 1 includes a  
20  $\lambda/4$ -, a  $\lambda/2$ - and a further  $\lambda/4$  delay element, these delay elements being disposed one behind the other and each being adjustable, i.e., rotatable. The three degrees of freedom of the polarization-controlling device are regulated by regulating device 4 in accordance with the above method. Using  
25 the entire device 3, each desired polarization is able to be converted into another desired polarization. Delay elements can include liquid crystal elements, electrooptic crystals, or mechanically, electromotively or piezoelectrically adjustable delay elements, such as fiber loops.

30 Figure 2 depicts one specific embodiment of the present invention, where polarization-controlling device 3 is configured downstream from the communication system which includes transmission medium 5 having at least one section 5'' exhibiting a preferred birefringence. Situated in this  
35 specific embodiment downstream from the polarization-controlling device, is an analyzer 6, which

absorbs or deflects the signal-spreading or signal-distorting polarization components of the optical information flow, depending on the specific embodiment of the analyzer. A small portion of the information flow is split off by beam splitter 5 7 and supplied to detector 8. Its output signal is fed to a regulating device 2, which generates a signal Q that is a measure of the transmission quality. This signal, in turn, is the input quantity for regulating device 4, which drives polarization-controlling device 3. In the described specific 10 embodiment of the present invention, analyzer 6, as described above, includes a linear polarizer, so that the polarization-controlling element merely needs to still transform any particular polarization state into a fixed, linear polarization state. This can be done using a  $\lambda/4$ - and a 15  $\lambda/2$ -delay element, which are disposed in series and are each adjustable, i.e., rotatable.

The polarization-controlling device is optimally adjusted when the light which, in the fiber member having preferred 20 birefringence, assumed the one main polarization state, is imaged onto the light having the transmit polarization of the analyzer, whereas the light, which assumed the other polarization state, is imaged onto the light having the blocking polarization state of the linear polarizer. The light 25 which is imaged onto the transmit polarization of the analyzer should preferably exhibit the higher intensity portion of the entire signal intensity. For this reason, the control unit is set up such that, in response to too low optical intensity of the information flow downstream from the analyzer, it switches 30 over to the other main polarization direction of the section of the communication system, preferably fiber member 5", having the preferred birefringence.

In place of beam splitter 7 and detector 8 in Figures 1 and 2, 35 another specific embodiment of the present invention provides that the transmission quality be measured at the same time that the information itself is detected, directly by the main

detector at the output of the transmission link.

What is claimed is:

1. A method for reducing the distortion of optical pulses (I) in an optical communication systems (1) caused by polarization mode dispersion, wherein, functioning in response to the detected transmission quality of the communication system, a polarization-controlling device (3) for adjusting the polarization of the optical pulse is driven in such a way that the transmission quality is maximized.
2. The method as recited in Claim 1, wherein, to optimize the communication, the polarization is reset in predefined time intervals.
3. The method as recited in Claim 1 or 2, wherein the polarization of the optical signal (I) is controlled at the beginning of the optical communication system.
4. The method as recited in Claim 1 or 2, wherein, using the polarization-controlling device (3), the polarization of the optical pulses is altered at the end of the optical communication system (5), and, following the optical communication system, the signal (I) propagates through an analyzer (6).

5. An optical communication system (1) having reducible distortion of the optical pulses propagating through the system, for implementing the method as recited in one of the Claims 1 through 4, comprising
  - an optical transmission medium;
  - a device (2) for determining the transmission quality of the communication system, whose output signal is applied to the input
  - of a regulating device (4), which drives a
  - polarization-controlling device (3) for changing the polarization of the optical pulses such that the transmission quality is optimized.
6. The optical communication system as recited in Claim 5, wherein the polarization-controlling device (3) is positioned at the input of the transmission medium.
7. The optical communication system as recited in Claim 5, wherein the polarization-controlling device (3) is positioned at the output of the transmission medium and, in addition, an analyzer (6) is positioned in the propagation direction of the light, downstream from the polarization-controlling device (3).
8. The optical communication system as recited in one of the Claims 5 through 7, wherein the polarization-controlling device (3) includes a  $\lambda/4$  delay element, a  $\lambda/2$  delay element and a further  $\lambda/4$  delay element, the delay elements being situated in this sequence, in series, and each being adjustable.
9. The optical communication system as recited in Claim 7, wherein the analyzer (6) is a linear analyzer, and the polarization-controlling device (3) includes a  $\lambda/4$ - and a  $\lambda/2$ -delay element, which are adjustable.

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10. The optical communication system as recited in one of the preceding Claims 5 through 9,  
wherein at least one delay element includes a liquid crystal element.
  11. The optical communication system as recited in one of the preceding Claims 5 through 10,  
wherein at least one delay element includes an electro-optical crystal.
  12. The optical communication system as recited in one of the preceding Claims 5 through 11,  
wherein at least one delay element includes a mechanically, electromotively or piezoelectrically adjustable element of three fiber loops.

## Abstract

Reducing the distortion of optical pulses caused by the polarization mode dispersion in optical communication systems.

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When an optical pulse having any polarization at all is transmitted through an optical communication system, which is optically anisotropic, at least in sections, the optical pulse generally becomes distorted due to the different velocities of 10 the various polarization components. This distortion of the optical pulses reduces, in particular, the maximum transmission rate of the system.

A remedy is provided, on the one hand, by a method where, 15 functioning in response to the detected transmission quality of the communication system, a polarization-controlling device for setting the polarization of the optical pulse is driven in such a way that the transmission quality is maximized and, on the other hand, by an optical communication system, which 20 includes an optical transmission medium, a device for determining the transmission quality of the communication system, a regulating device, and a polarization-controlling device. The output signal from the device for determining the transmission quality of the communication system is applied to 25 the regulating device, which drives the polarization-controlling device to change the polarization of the optical pulses in such a way that the transmission quality is optimized.

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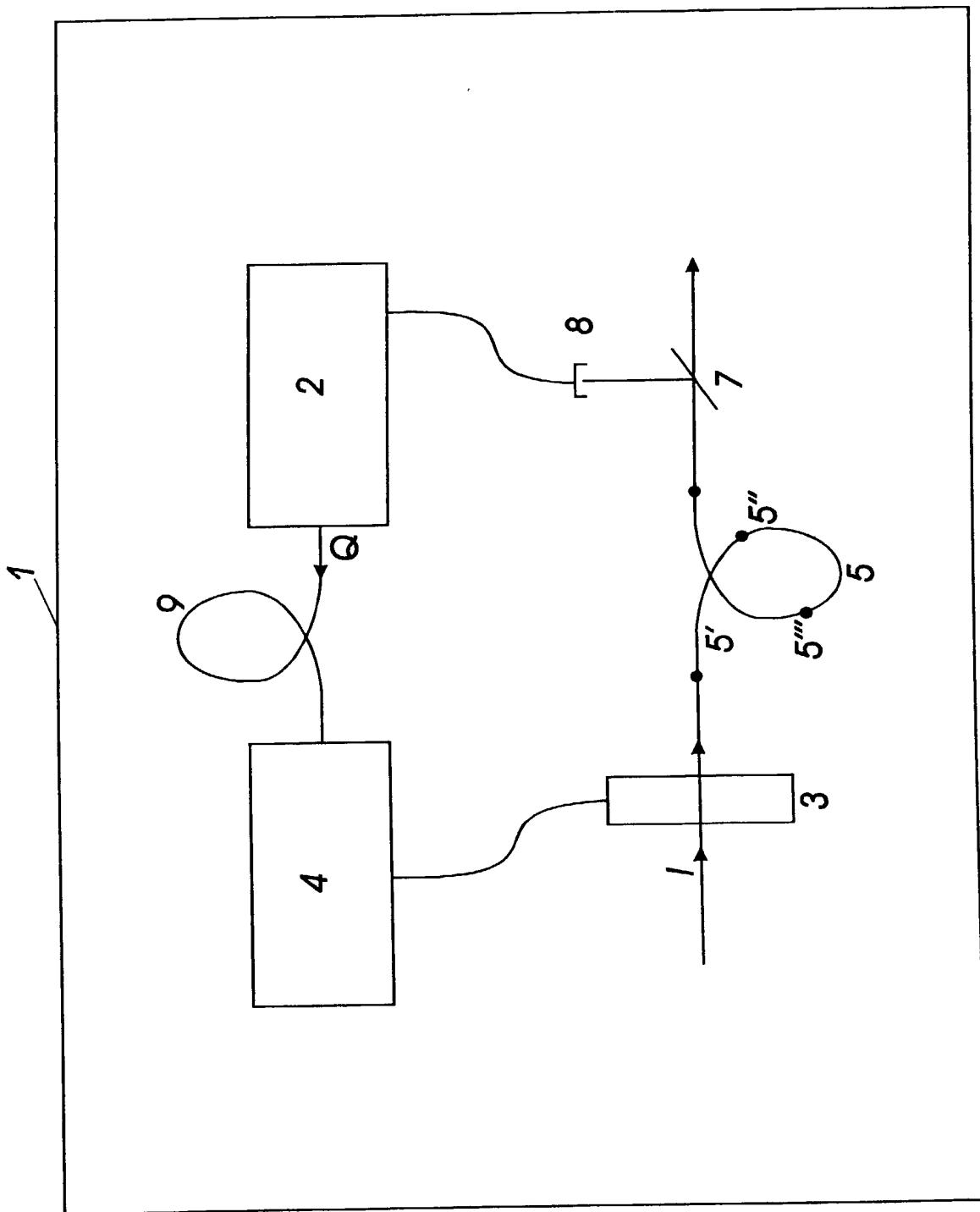


Fig. 1

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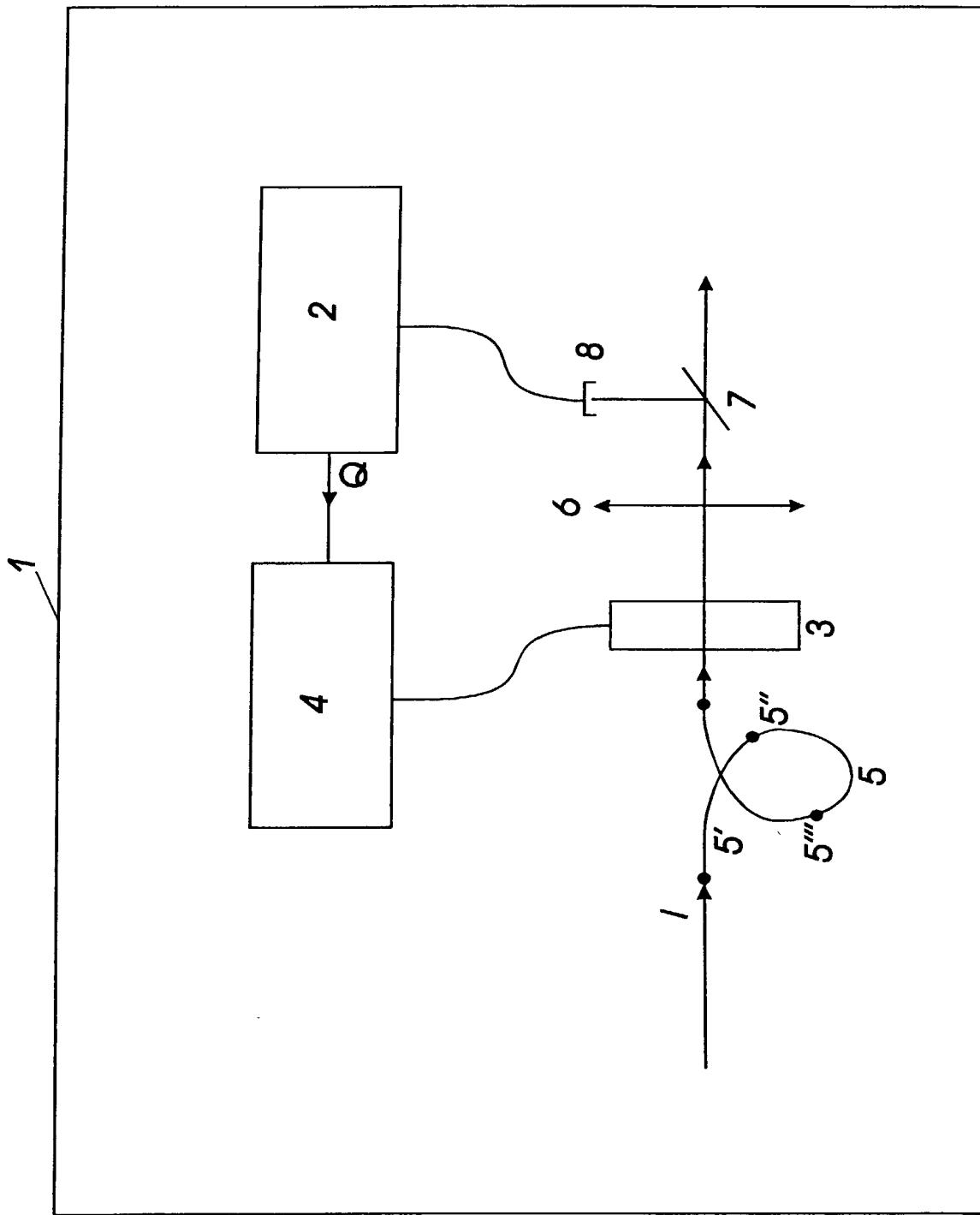


Fig. 2

**DECLARATION AND POWER OF ATTORNEY**

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **REDUCTION OF THE DISTORTION OF OPTICAL IMPULSES THROUGH POLARISATION MODE DISPERSION IN OPTICAL TRANSMISSION SYSTEMS**, the specification of which was filed as International Application No. PCT/EP00/00320 on January 17, 2000 and filed as a U.S. application having Serial No. 09/890597 on August 3, 2001 for Letters Patent in the U.S. Patent and Trademark Office.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application(s) for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

**PRIOR FOREIGN APPLICATION(S)**

Number	Country Filed	Day/Month/Year	Priority Claimed Under 35 USC 119
199 04 137.7	Fed. Rep. of Germany	February 3, 1999	Yes

3/ And I hereby appoint Richard L. Mayer (Reg. No. 22,490), Gerard A. Messina (Reg. No. 35,952) and Linda M. Shudy (Reg. No. 47,084) my attorneys with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

Please address all communications regarding this application to:

KENYON & KENYON  
One Broadway  
New York, New York 10004

**CUSTOMER NO. 26646**

Please direct all telephone calls to Richard L. Mayer at (212) 425-7200.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful and false statements may jeopardize the validity of the application or any patent issued thereon.

Inventor: **Wolfgang DULTZ**

Inventor's Signature: W. Dultz

Date: 21.2.2002

Residence: Marienberger Str. 37  
D-65936 Frankfurt am Main  
Federal Republic of Germany DEX

Citizenship: German

Office Address: Same as above.

*2-0*  
Inventor: Leonid BERESNEV

Inventor's Signature: 

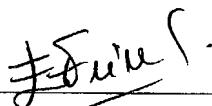
Date: x February 23, 2002

Residence: 10730 Faulkner Ridge Circle  
Columbia, Maryland <sup>MD</sup> 21044  
United States of America

Citizenship: Russian

Office Address: Same as above.

b-8 Inventor: Erna FRINS

Inventor's Signature: 

Date: 27. February, 2002

Residence: Sepée 1748, Casa 6  
11400 Montevideo  
URUGUAY UX

Citizenship: Uruguayan

Office Address: Same as above.

*X80*  
Inventor: Franko KUEPPERS

Inventor's Signature: F. L. ~

Date: March 2, 2002

Residence: Pupinweg 3  
D-64295 Darmstadt  
Federal Republic of Germany DE X

Citizenship: German

Office Address: Same as above.

5-00

Inventor: Heidrun SCHMITZER

Inventor's Signature: Dr. H. Schmitzer

Date: 25. February 2002

Residence: Am Feld 29  
09123 Chemnitz/Einsiedel  
Federal Republic of Germany DEX

Citizenship: German

Office Address: Same as above.

6

Inventor:

Joachim VOBIAN

Inventor's Signature:



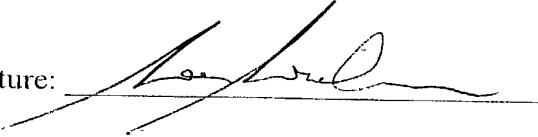
Date: 05<sup>th</sup> March 2002

Residence: Am Hang 6  
D-64367 Muehlthal  
Federal Republic of Germany 

Citizenship: German

Office Address: Same as above.

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Inventor: Werner WEIERSHAUSEN

Inventor's Signature: 

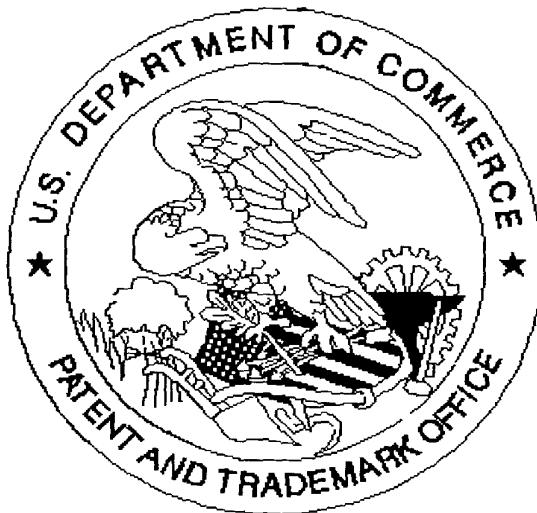
Date: 8.4.2002

Residence: Alte Darmstaedter Str. 17  
D-64367 Muehlthal  
Federal Republic of Germany **DEX**

Citizenship: German

Office Address: Same as above.

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